BUILDING WITH FLAX AND HEMP
# Table of Contents

- Flax and hemp 4
  - History 4
  - Conditions 4
- Flax and hemp based building materials 5
  - LCA & labels 5
  - Recyclable 5
  - Advantages 6
  - Disadvantages 6
- Useful parts of the plants 7
  - Fibers 7
  - Shives 8
  - Seeds 8
  - Dust 8
- Construction applications 10
  - Insulation materials Hemp 10
  - Insulation materials Flax 10
  - Non-wovens 14
  - Composites 14
  - Hemp lime 16
  - Chipboards / particle boards 24
  - Wall plastering 25
  - Linseed oil and natural paints 26
  - Linoleum 27
- Examples 28
- Grow2Build 30
  - Aim project 30
  - Aim brochure 30
- Bibliography 31
  - Publications 31
  - Articles 31
Flax and Hemp

History

Hemp and flax are historic crops in North-West Europe. Until the 19th century, hemp and flax were widely used for the production of rope and textile. At the beginning of the 20th century, cheaper imported fibers such as cotton, synthetics (nylon, PP), supplanted hemp and flax. Furthermore, after the ban on growing cannabis in the U.S.A. - that recognized no difference between marihuana and industrial hemp -, Europe soon adopted this policy. It was only until 1992 European farmers were back allowed to grow industrial hemp.

Nowadays, there are revivals in many industrialised countries. Hemp and flax fibers/shives are being promoted for use in insulation, as reinforcement for composites, in chipboards, etc. Hemp and flax seed oil are used in paints, coatings and linoleum.

Conditions

Producers of building products need a consistent quality of the fibers and shives. The quality is strongly influenced by the retting degree and the primary process conditions.

To guarantee a consistent production of building materials, there should be a sufficient crop volume each year. Close cooperation between farmers, primary processors and manufacturers is advantageous.

LCA & labels

For an LCA, the entire environmental impact of a product from cradle to grave is taken into account. This process starts with the extracting of raw materials and ends with the processing of waste. All the phases in between such as production, transport are taken into consideration in the analysis. This gives the producer insight in the product related environmental effects during every phase of the product’s life cycle.1

The nibe classifications (Dutch, www.nibe.info) show the environmental impact of different applications of hemp and flax building materials. Although these can give a very interesting insight, keep in mind such classifications can be open to interpretation.

At the CAP’EM compass, all kinds of natural building materials can be compared. (www.capemcompass.eu). Several flax and hemp building products obtained eco- and health labels (e.g. natureplus).

Recyclability

The recyclability of flax and hemp building materials depends on the specific product. Hemplime is compostable as it is made only from natural elements (hemp, lime, water). Insulation slabs often contain some fire retardant additives (like boron salts), therefore the technical datasheets and/or the producer should always be consulted prior to recycling. Composite materials can be recycled but this also depends on the specific product and tends to be more difficult in general.
Advantages

- Local crop. NW Europe is a very good region to grow flax and hemp.
- Fast Growth. It only takes 4 to 6 months from seeding till harvest.
- Natural fibers
- The fiber based building materials do not cause skin irritations during installation.
- They have a positive CO2 balance.
- High moisturising
  - The moisturising effect of the fiber ensures that moisture is absorbed in high humid climate conditions and the moisture released at a low relative humidity. The use of flax or hemp insulation has a positive effect on the indoor climate.
- High thermal energy storage
  - The materials have a higher heat capacity than conventional insulation materials. The time that the heat (energy) needs to pass through the insulation material, is four times as long as with other materials.
- High insulation
  - Both thermal and acoustic insulation show excellent values. The open structure ensures absorption of vibrations and air movement (sound waves) conversion by friction into heat.
- Light weight fibers
- High stiffness
- High strength (fibers)

Disadvantages

- Additives
  - Since the insulation is not fire resistance, additives, such as ammonium phosphate, should be added (15-20%) to meet the requirements regarding fire safety.
- Susceptible to decay by micro-organisms.
  - Since the fibers are hygroscopic and absorb moisture in, humid conditions the risk of degradation by micro-organisms increases. To extend the lifetime, antimicrobial products are often added.\(^2\)
- Price
  - Since the products are produced in relative small volumes, the cost prices are still high.

The standards for technical properties have been developed for traditional building products. These indicators show a limited number of properties of the product performance. However, there are more relevant indicators that should be tested and communicated. For certification, bio-based materials are compared with traditional building materials (lambda values, etc). Though, characteristics and corresponding performances are diverse, making it impossible to compare. Standardised national and international testing and evaluation procedures for biobased building products would also increase understanding among developers, architects and installers and accelerate the maturity of the industry. The provision of objective information on the performance (and guarantee of performance) of available technologies can boost customers’ acceptance and accelerate deployment (EEB).

Useful parts of the plants

Fibers

In North-West Europe, flax is grown to cultivate long fibers. Most of these long fibers are exported to countries like China for textile production. Short fibers from flax and hemp are used in technical applications.

Building applications: technical textile (long fibers) - composites, insulation, non-wovens (short fibers)
Shives

The wooden part of the flax / hemp stem. The shives absorb water up to 3,5 to 4 times their weight. They have thermal and acoustic qualities.

Building applications: chipboards, particle boards, hemcrete (hempshives in combination with lime), wall plaster.

Seeds

Hemp and flax seeds can be used as oil. They can be mixed with other substances to produce paints. The oil can also be used as an impregnation of wood and other porous surfaces.

Building applications: linseed oil, natural paint, linoleum

Dust

Flax dust can serve as a source of energy by processing it into biogas.

Building applications: energy
CONSTRUCTION APPLICATIONS

Insulation materials Hemp

Properties
- Both flexible slabs and compressed boards (non-woven blankets / felts / panels)
- High acoustic damping values, because the fibers can absorb broad frequency range vibrations
- Good fire properties with flame retardants / no-dripping effects

Composition
- Technical (short) hemp fiber
- Support fiber (polyester or starch)
- Ammonium polyphosphate (flame retardant)
- Boron salts (mildew resistant)

Technical
- Thermal conductivity (λ): 0.040 - 0.042 W/mK
- Heat storage (c): 2100 - 2500 J/kgK
- Diffusion resistance (vapor permeability) μ: 1 - 10
- Unit mass (ρ): 30 - 36 kg/m³
- Fire class: m1 according to NF P 92-507

Insulation materials Flax

Properties
- Both flexible slabs and compressed boards (non-woven blankets / felts / panels)
- High acoustic damping values, because the fibers can absorb broad frequency range vibrations
- Good fire properties with flame retardants / no-dripping effects

Composition
- Technical (short) flax fiber
- Support fiber / binder (polyester or starch)
- Ammonium polyphosphate (flame retardant)
- Boron salts (mildew resistant)

Technical
- Thermal conductivity (λ): 0.038 - 0.040 W/mK
- Heat storage (c): 1550 - 1600 J/kgK
- Diffusion resistance (vapor permeability) μ: 1 - 2
- Unit mass (ρ): 20 - 30 kg/m³
- Fire class: m1 according to NF P 92-507

Producers
A list of producers is available on www.grow2build.eu

Applications
The applications of flax and hemp insulation are the same as traditional insulation materials, such as mineral wools.

VIBE vzw: Natuurlijk Isoleren. Lannoo, Tielt, 2014, pp. 52-53
Instead of a concrete slab, you can also choose for shells or glass foam granulate. Both can be used as foundation and waterproofing.

**Vertical section foundation**

1. Cladding
2. Battens
3. Sarking board
4. Timber frame with flax and/or hemp insulation
5. Osb / sarking board + airtight tape
6. Piping cavity filled with flax insulation
7. Plasterboard
8. Window frame
9. Air tightness
10. Concrete slab / shells
11. Screed
12. Hemp lime
13. Plinth
14. Waterproof insulating blocks
15. Floor finish

**Vertical section window**

1. Cladding
2. Battens
3. Sarking board
4. Timber frame with flax and/or hemp insulation
5. Osb / sarking board + airtight tape
6. Piping cavity filled with flax insulation
7. Plasterboard
8. Window frame
9. Air tightness
10. Wind seal
Non-wovens

Non-wovens are a manufactured sheet of directionally or randomly oriented fibers. Nonwovens are bonded by friction, cohesion or adhesion. This can be by chemical, mechanical, heat or solvent treatment. The fibers are of natural origin. They may be staple, continuous or be formed in situ.

Properties / Composition
The properties and the composition of a nonwoven depend on the used fibers and production process.

Production process (Ecotechnilin)5
The carding/cross lapping/needle punching process
• Carding: This process aims to parallelise and individualise the fibers to create a consistent and resistant veil.
• Cross lapping: This step aims to superimpose several layers of veil in order to obtain the desired weight of mat. Therefore, the consolidation of needle punched products is only made mechanically, without any chemical binder.
• Needle punching: This process uses barbed needles to interlink fibers to form a consistent and strong nonwoven mat. Therefore, the consolidation of needle punched products is only made mechanically, without any chemical binder.

Applications
• Acoustic and thermal insulation e.g. subfloor to improve comfort and reduce noise transfer to other rooms.
• Semi-finished product for composites.

Producers
• A list of producers is available on www.grow2build.eu

Composites

Fiber reinforced polymer composites (FRP), generally consist of two main components: reinforcing fibers and a polymer matrix. Natural fiber reinforced polymers (NFRP) offer a potential alternative to GRPs (glass fiber reinforced polymer) and could prove to have a lower embodied environmental impact. They can be used in structural and architectural applications such as, beams or exterior cladding.

Natural fibers, such as hemp and flax, display similar mechanical properties and characteristics to glass fibers. Natural fibers are used for reinforcement in yams, woven or non-woven mats and chopped fibers. Natural fibers offer the advantage that they are not abrasive to machinery, they are less harmful to humans and are obtained from renewable sources.

Properties and the composition of a nonwoven depend on the used fibers and production process.

The weight of a material is a key consideration in application, as a lower weight can reduce costs in some areas of manufacture, fabrication, transportation and construction. The low density of natural fibers also results in a lower thermal conductivity in certain configurations, suggesting that an NFRP could perform well where thermal bridging is a concern, e.g. window frames or secondary structural elements such as wall ties.

When natural fiber reinforcement is combined with a bio-derived polymer, such as cashew nut shell liquid oil (CNSL), a fully biodegradable composite or ‘bio-composite’ is produced, further reducing the environmental impact of the material.

Advantages6
• High rigidity, reasonable strength
• Low density
• Renewable
• Material itself is 100% CO2 neutral
• Moisturising: can make contribution to indoor climate control
• Low coefficient of thermal expansion

Cons7
• Finite length (fiber spinning into infinite yams introduces a twist in the fibers which reduces the ‘effective fiber strength’)
• Inhomogeneous dimensions and composition
• Absorbent: removing moisture is needed for processing
• Fogging and smell during and after processing

Composition
• Fibers
• Matrix (e.g. Polymers, resins, cements)
• Accelerator, compatibiliser

Technical
Tensile properties and densities of natural fibers8
• Flax
  strenght: 500-1100 MPa
  stiffness: 50-70 GPa
  fracture strain: 1.3-3.3 %
  density: 1.5 g/cm³
• Hemp
  strenght: 400-800 MPa
  stiffness: 30-60 GPa
  fracture strain: 1.6-4 %
  density: 1.48 g/cm³

Morphological properties of natural fibers9
• Flax
  length fiber bundle: 300-900 mm
  length plant cell: 13-60 mm
  diameter fiber bundle: 50-200 micrometer
  diameter plant cell: 12-30 micrometer
  Fibril angle: 10°
• Hemp
  length fiber bundle: 1000-3000 mm
  length plant cell: 5-55 mm
  diameter fiber bundle: 50-200 micrometer
  diameter plant cell: 16-80 micrometer
  Fibril angle: 6.2°

Applications
Cladding, furniture, washbasin, flooring...

References
5 www.ecotechnilin.com/activity-process.asp
6 www.ecotechnilin.com/activity-process.asp
7 Biocomposites 2012, Natuurlijke vezels en bioharsen in technische toepassingen, Martien van den Oever, Karin Molenveld, Wageningen UR
8 Mukhopadhyay, 1989; Bisanda, 1992; Davies, 1998; Tripathy, 2000; Ruys, 2002; Defoirdt, 2010; van Dam, 2011
9 van Dam, 2011; Bisanda, 1992; Bos et al., 2002
Hemplime

Hemplime is used as insulation in walls, floors and roofs. It has no bearing capacity, so it must always be combined with a bearing structure, such as a timber frame or brick wall. It can be applied both as blocks, as a sliding formwork and as sprayed.

Hemp shives and lime alternates, depending on; the application, the producer and the proportion of water. There is always a pozzolanic binder as additive.

There are several projects that are developing hemp lime with a bearing structure. In the UK, a method is developed to combine the block with a bearing structure. The production is situated in the Netherlands. A Belgian company is developing the combination of steel structure with hemp lime sliding formwork.

Properties

• High thermal inertia value
• High moisture absorbing
• Vapor open
• Very good fire properties

Composition

• Hempshives
• Water
• Lime (hydraulic / hydrated)
• Binder as additive (often lime or cement)

Technical

• Hemplime blocks
• Thermal conductivity (λ): 0.07 W/km
• Unit mass (ρ): 360 kg/m³
• Fire class: Euroclass B,

Applications

Hemplime can be used as insulation in floors, walls and roofs. It can also be used as a non-bearing (inner) wall.

Vertical section roof hemplime + plaster

1. Roof sheathing
2. Roof battens
3. Sarking board
4. Wind seal
5. Hemplime
6. Timber board
7. Reed mat or osb / sterling board
8. Piping cavity filled with flax insulation
9. Plasterboard
10. Top plate
11. Timber frame with hemplime
12. Plaster (clay or lime)
13. Plaster finishing (trass lime)
1. Plaster finishing (trass lime)
2. Timber frame
3. Hemplime
4. Plaster (clay or lime)
5. Window frame

Vertical section window hemplime + plaster

1. Cladding
2. Battens
3. Sarking board/membrane
4. Hemplime
5. Plaster (clay or lime)
6. Timber frame
7. Window frame

Vertical section window hemplime + cladding
Horizontal section window
1. Window frame
2. Timber frame
3. Plaster finishing (trass lime)
4. Hemp lime
5. Plaster (clay or lime)
6. Plaster profile

Vertical section foundation hemp lime + plaster
1. Plaster finishing (trass lime)
2. Timber frame
3. Hemp lime
4. Plaster (clay or lime)
5. Profile
6. Plinth
7. Water barrier
8. Waterproof insulating blocks
9. Vapour barrier
10. Concrete slab
11. Screed
12. Hemp lime
13. Floor finish
Vertical section foundation – insulation exterior

1. Plaster finishing (trass lime)
2. Hemplime (blocks or sliding formwork)
3. Existing bearing wall
4. Plaster (clay or lime)
5. Water barrier membrane
6. Supporting profile
7. Plinth
8. Waterproof insulation
9. Concrete slab
10. Screed
11. Hemplime
12. Floor finishing

Because hemplime is moisture-retaining, it is also possible to use it as an inner insulation. However, preference must still go to outside wall insulation. This may only be used if it is not possible to insulate from the outside.

Vertical section foundation – insulation interior

1. Existing bearing wall
2. Hemplime (blocks or sliding formwork)
3. Plaster (clay or lime)
4. Water proofing barrier
5. Concrete slab
6. Screed
7. Hemplime
8. Floor finish
Chipboards / particle boards

Fiberboards that are made with flax shives. These boards have high acoustic and thermal qualities.

They are used as inner part of doors, as structural elements in timber frame structures, for furniture, as ceiling.

Properties

- Constant, homogeneous quality
- Low weight
- Fine structure

Composition

- Flax shives
- Water
- Resin
- Hardener

Applications

Inner parts of doors, wall panels, floors

A specific application of chipboards with flax shives are acoustic boards. These are specific used as sound insulation. The boards are made of recycled cellulose (paper pulp), reinforced with flax shives and resin.

Technical

The values vary according to the mass of the panels.

Producers

A list of producers is available on www.grow2build.eu

Wall plastering

Lime hemp plaster is comparable with hemplime, but in the application of plastering. The addition of hemp fibers improves the strength and flexibility of the product. It also increases the thermal properties of the plaster and is an excellent way of adding some extra insulation to your wall.

Properties

- Natural and renewable
- More flexural strength than traditional lime plasters (more resilient for use on vulnerable areas of the building)
- Helps to improve the insulation performance of the wall
- Addition to the thermal mass (warm in winter and cool in summer)
- Improves the airtightness of old buildings
- Can be applied in thick coats (between 10-50mm): useful for ‘dubbing out’ hollows in walls
- Minimal shrinkage on high suction backgrounds
- Helps to regulate humidity (breathable)

Composition

- Non-hydraulic lime
- Hemp fibres
- A pozzolan
- Water

Technical values

Technical values of hemplime are comparable, depending on the thickness of the plaster and the manufacturer.

Applications

- Plastering on conventional backgrounds
- Dubbing out (internally/externally) the wall prior to plastering
- Restoration of old ‘solid wall’ construction buildings (breathable)
Linseed oil and natural paints

Linseed oil that is obtained from dried, ripened seeds of the flax plant. The oil is obtained by pressing (seeds are 40% oil), sometimes followed by solvent extraction. Linseed oil is a drying oil: it can polymerise into a solid form. It is used on its own or blended with other oils, resins and solvents.

“Raw” linseed oil is squeezed from flax seed with no additional additives or preservatives. Raw linseed oil dries very slowly, taking weeks to fully dry. It is used in applications for elements where drying time is not an issue.

“Boiled” linseed oil is not boiled. It is the addition of certain solvents that causes linseed oil to dry more quickly, acting as if it were boiled.

Properties
• Breathable coating which regulates moisture
• Hardens by a reaction with oxygen but maintains elasticity of surface.
• Recyclable
• Dries up slowly, but uniformly
• Protection from water
• Binds different ingredients
• Has to be applied very thin (otherwise it will wrinkle and not dry properly)

Composition
• Linolenic acid >50%
• Linoleic acid 10-20%
• Oleic acid 10-20%
• Stearic acid <10%
• Palmitic acid +/- 5%
• Eicosene acid <1%
• Erucic acid <1%

Pigments and curing agents are added. Depending on the producer, they are natural, degradable and/or renewable pigments.

Applications
• Impregnator and varnish in wood finishing
• Pigment binder in oil paints
• Plasticiser and hardener in putty
• Component of linoleum

Producers
A list of producers is available on www.grow2build.eu

Linoleum

Linoleum is used as flooring and upholstery. Due to its wear resistance and hygienic characteristics, it is often used in schools, hospitals, public areas ...

Properties
• Thermal conductivity (compatible with underfloor heating)
• Biodegradable
• Durable
• Bacteriostatic

Composition
• Linseed oil
• Rosin (tree resin)
• Cork and/or wood flour
• Limestone powder
• Colour pigments
• Pressed onto a hessian (woven from jute plant fibres)

Technical values
Depending on the manufacturer and type of linoleum, the technical values are different.

Producers
A list of producers is available on www.grow2build.eu

Manufacturing process

Flooring and furniture: both glued as mechanical.

Linoleum flooring
Roof insulation hemp lime
Barchi
Model at mobile exhibition Grow2Build

Construction site
Peter Steen
Model 1:1 at demonstration site
Bas Veurne
Aim project

Grow2Build works on the transition of the North West European economy from a fossil oil based economy towards a bio-based economy. Special attention must be emphasised on the integration of local sustainable cultivation of resources in this future oriented economy. Grow2Build focuses specifically on hemp and flax based building materials: Grow2Build wants to tackle the remaining bottlenecks through the whole supply and value chains of hemp and flax based building materials as well as in the marketing of those products so that this bio-economical business can develop in a sustainable and profitable way within NWE region.

Aim brochure

In this brochure, we focus on the practical applications of the flax and hemp based building materials. To support architects, contractors, engineers, students. For professionals who want to work with the materials, but don’t know how to apply in buildings, we’ve developed this brochure.

Complementary to this brochure:

- Brochure general public
- Brochure cultivation
- Benchmark report (overview of the current situation)
- Gis map (location of all stakeholders)
- Catalogue of labels
- Fact sheets about project pilots

Available on www.grow2build.eu or with the project partners.

BIBLIOGRAPHY

Publications


Articles


Growing hemp
Rattling of flax